

ENGINEERING SYSTEMS FOR WASTE DISPOSAL TO THE OCEAN[#]

by

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Marine Waste Disposal as an Engineering System.

Successful waste-water and sludge disposal in the ocean depends on designing an appropriate engineering system where the input is the waste and the output is the final water quality which is achieved in the vicinity of the disposal site. The principal variable components of this system are:

- source control (or pretreatment) of industrial wastes before discharge into municipal sewers;
- sewage treatment plants, including facilities for processing of sewage solids (sludge);

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#Paper presented at the Symposium on Engineering Aspects of Using the Assimilative Capacity of the Oceans, June 23-24, 1981 at Lewes, Delaware (sponsored by the Marine Board, National Research Council).

- outfall pipes and diffusers for dispersal of effluents into the ocean, and either barges or pipelines for disposal of sewage sludge.

There are important trade-offs between these three components of a system. Until now regulatory policies have tended to give little recognition to outfall technology and have concentrated largely on sewage treatment at central plants and source control. However, Section 301(h) of the 1977 amendments of the Federal Water Pollution Control Act was an important change which allows an ocean discharger to apply, under certain conditions, for a waiver from the mandatory secondary treatment requirement.

Regulations which set ambient water quality standards, rather than effluent standards, allow the most cost-effective system to be designed. On the other hand, if a certain technology is specified (e.g., secondary treatment), then there is no incentive for devising cost-effective high dilution outfall systems.

Engineering Design of Sewer Outfalls for Effluent.

The design procedure for an ocean outfall with a diffuser for effluent discharge is depicted in Figure 1. Inputs (the top boxes in the the figure) include:

- (1) The water quality objectives and requirements which are set forth by the regulatory authorities and/or the discharge agency.
- (2) The environmental factors of the proposed site including a full range of physical, chemical, and biological data

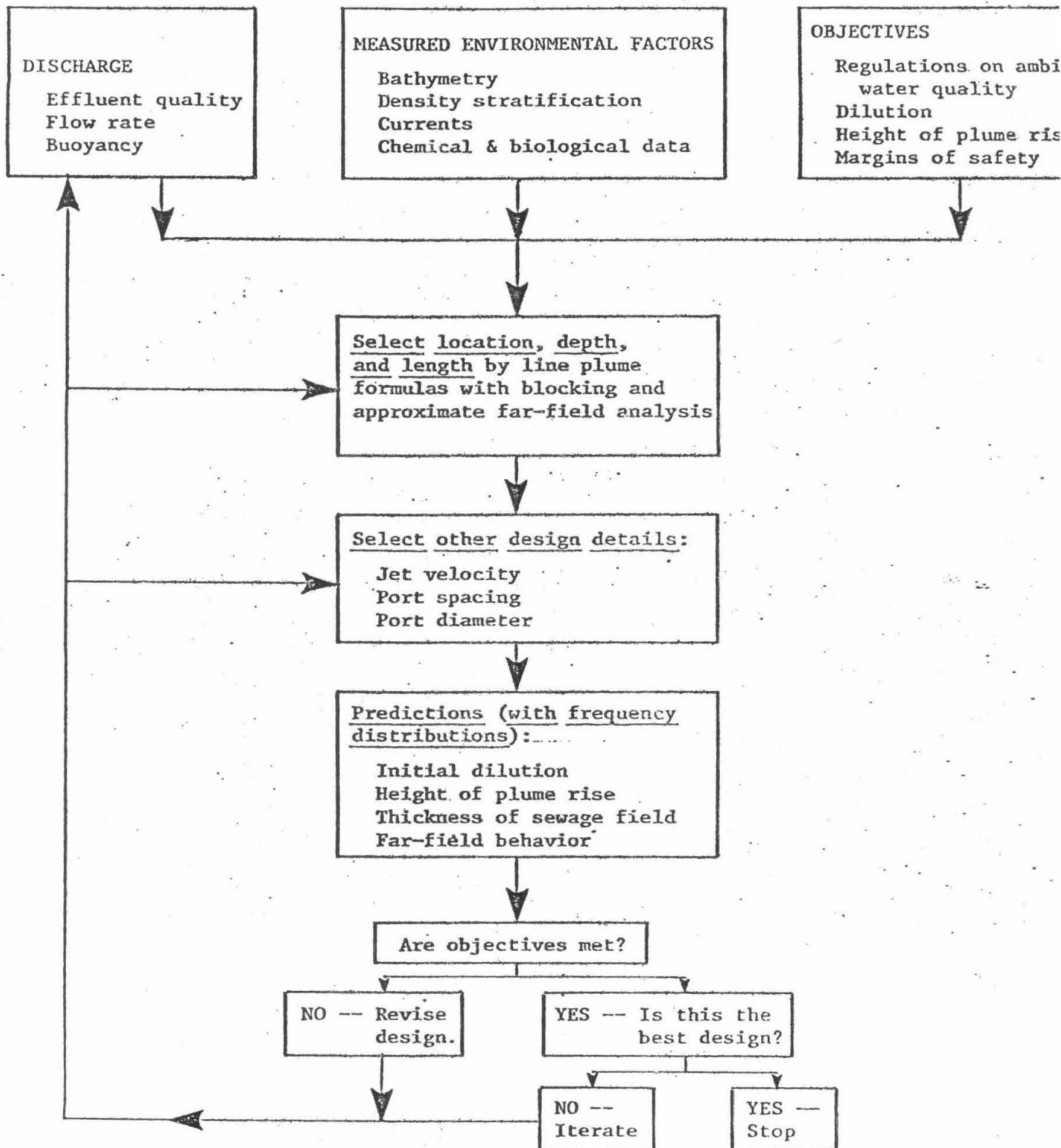


FIGURE 1: -- Design Procedure for Sewage Outfall with Diffuser.

gathered over at least a year's time. This information defines not only the environment in which the plume mixing and dispersion occur but also the undisturbed pre-discharge condition. The plume behavior is strongly affected by density stratification and currents. For the structural engineering design, it is also necessary to have a detailed bathymetric map, information on the wave environment, and geotechnical investigations of foundation conditions.

- (3) The effluent quality and flow rates. The quality is determined by the degree of treatment (e.g., primary or secondary) and the degree of control of trace contaminants at their sources (or pretreatment). The buoyancy of the effluent relative to sea water is also important in the dynamics of the plumes.

With these inputs, a trial outfall design may be developed by procedures described elsewhere (Fischer, et al., 1979; Koh and Brooks, 1975; Grace, 1978). The site of the outfall is dictated by both nearfield and farfield requirements, while the diffuser length and port details are primarily based on the nearfield dilution and submergence objectives. The fluid dynamics of initial dilution calculations is well in hand, as is the hydraulic design of large diffusion structures. While experience with outfall designs has been very good on the West Coast, there are still important research needs for more detailed after-the-fact analyses of outfall performance, both nearfield and farfield.

With a trial design, both the nearfield and farfield water quality can be predicted in detail for the full range of the variable environmental parameters and flows for comparison with the objectives. These predictions have frequency distributions in response to the temporal variations in the inputs (currents, stratification, flow). If the objectives are not met, or the optimum system is not obtained then the system is adjusted by changing the treatment (or pretreatment) and/or the physical location and design of the outfall. (A reasonable margin of safety should be allowed to accomodate uncertainties and errors in the predictions.) Occasionally the water quality objectives will also be modified if the cost of achieving them is exorbitant compared to the water quality benefits to be achieved. It is this overall systems view that is not captured in federal regulations.

In a sense we are starting with the objectives and working "backwards" to design a system which will be the optimal way to achieve them. The resulting system usually will involve certain trade-offs. For example, if a longer, deeper outfall is selected, then less treatment is needed (see Appendix, Table 1). If trace contaminants cause problems, they need to be solved at the sources, because with more advanced treatment at the municipal plant more trace contaminants are caught in the sludge which will still have to go somewhere.

Apart from the current regulatory constraints, the top priority technical problems for waste-water disposal in the ocean are the control of emissions of trace contaminants to safe levels, and the avoidance of excessive concentrations of sewage particles either in the water column or accumulating on the bottom. Removal of BOD (biochemical

oxygen demand) by secondary treatment is usually not a priority problem, in contrast to many freshwater disposal situations. Trace contaminants can probably best be controlled at the sources (rather than by sewage treatment), while particles are primarily removed by sedimentation, which is sometimes enhanced by additions of polymers or other flocculating agents.

To me the term "assimilative capacity" is not a useful concept because it tends to imply that up to a certain point everything is fine, and then beyond that point things are bad. Instead it should be understood that any waste-water discharge in the ocean always has some effects (even if small), which depend on the system design as described above. When ocean disposal is used, however, these effects are believed to be much less than the effects of other possible engineering solutions of waste-water disposal, such as to land or inland waters.

Sludge Disposal.

Digested sludge disposal to the ocean may be accomplished either by barges or by special sludge outfall pipes. Although federal laws essentially ban ocean dumping of sludge after 1981, there appears to be a lack of scientific or engineering bases for such outright bans. There is a range of possible ways to design the discharge operations (e.g., different depths or distances from shore, and different techniques of dispersal or containment). Recent advances have been made in predictive modelling for the effects of sludge disposal in the ocean (Jackson, et al., 1979) and within the next decade we should have a well-established methodology. The ocean

disposal option for digested sewage sludge could then be compared on a more rational basis with other alternatives which impact fresh water, land or air resources.

There is an urgent need for more experimentation on methods of disposing of sludge in the ocean through appropriate research and demonstration projects. One such project has been proposed by the Orange County Sanitation Districts, California (see Appendix, Table 2).

Conclusion.

While considerable progress has been made in developing design procedures for outfalls and barging systems, additional field research would lead to further advances in our knowledge and engineering capabilities. Furthermore, if the ocean disposal option is kept open for both sewage effluent and sludge, with appropriate flexibility for case-by-case evaluations and comparison with air, land, and freshwater options, then more effective overall management of wastewater disposal can be achieved.

In the design of an ocean disposal system, there are always uncertainties and risks due to incomplete knowledge of the marine environment and uncertainties in the predictions of performance. Whenever possible, it is wise to follow a course of action that permits some adjustments as we learn more and gain operating experience with a particular discharge. Feedback is essential!

The appendix to this paper, which is a hearing statement by Brooks and Krier, discusses the policy issues in the light of current regulations, the engineering state-of-the-art, and current knowledge about fates and effects of ocean discharges. It is based on the concluding chapter in a book sponsored by NOAA (1982).

DISCUSSION

CSANADY:

BROOKS: I am glad you brought that up because there are no zeroes in the environmental business. So the question is really how small is small enough for discharge of certain kinds of toxic substances to the ocean. It is true that no matter how good a job you do on source control or pretreatment you simply cannot reduce the toxic substances to zero. With the help of marine biologists, you have to identify which toxic substances have priority for source control and decide what limits are necessary for each substance to protect the marine environment. There has been a lot of debate about what the objectives should be. However, for small amounts of some toxic substances, the deep ocean may be a safer disposal site than anywhere else.

COLWELL:

BROOKS: That is a good question. I tend to think that it is better not to tangle the societal questions too much with the technical questions, in the following sense. Suppose you have three alternative ways of doing something. It is better to state what the engineering system is and what you believe the effects will be for systems A, B, and C, and also the actual costs of implementing A, B, and C. They will be different, and let the policymakers or the public debate whether the differences in costs in relation to the differences in effects are worth it. I am worried about an engineer or an analyst sweeping it all together in one overall cost, and saying that system X is cheapest when environmental costs are included; the problem is that the environmental cost factors are subjective, and the engineer's choices may be factors of 10 or 100 different from somebody else's choices. Some people say that it does not make any difference: who cares about the ocean? Some say that the ocean is invaluable. So I am saying, "We will just define what the alternatives would do and predict their effects as best as we can, and let the body politic debate which one is worth doing."

I think we have seen, in the last 10 years in the United States, a lack of debate of carefully reasoned alternatives with different costs and effects, because Congress just said, "You have got to have secondary treatment, and no ocean sludge dumping." So it seemed useless to define and debate the alternatives.

COLWELL:

BROOKS: Don't get me wrong. An engineer still should be very much aware of the biological and chemical implications in the design of disposal systems. For example, one of the benefits of making long outfalls is that you may not have to chlorinate in order to meet the bacterial requirements at the shore. In fact, the California Ocean Plan says that, where possible, outfalls should be long enough to avoid chlorination. There is no use in chlorination to meet coliform standards if the outfall discharge is far enough away from shore that natural dieoff and diffusion are sufficient for the coliform standards to be met.

KAMLET:

BROOKS: I would always start from the following point. If society has gotten itself into a corner when it has a certain amount of the PCB's to dispose of, then I would do a systematic analysis of all the ways in which PCB's can be disposed of, including the best possible way I could think of to put them in the ocean. Then I would compare that with the best possible way I could do it into other media (air and land) including dispersal and containment techniques, and choose the apparent best alternative overall. The engineering approach for a persistent contaminant must consider possible inter-media transfers, and cross-media comparison of effects. There is no such thing as an engineering solution for one medium when you are talking about such a material.

In fact, one of the truisms I pass on to you is that you really have two strategies for environmental management: either dispersal or containment. These can both be subjected to engineering approaches such as we heard yesterday from Professor Dexter on how to engineer a containment.

You get into problems when you do a bad job of dispersal -- because with poor dispersal the material is still hanging around too much--or when your containment is leaky. You just must not get yourself caught in the middle. You have got to follow either one strategy or the other and do it well. For example, for a landfill for hazardous wastes, you try to make it really leakproof so that the wastes cannot get out in the ground water. But if your strategy is dispersal in the ocean, be sure to do it well!

REFERENCES CITED

Fischer, Hugo B., E. John List, Robert C. Y. Koh, Jorg Imberger and Norman H. Brooks, 1979, Mixing in Inland and Coastal Waters, Academic Press, New York.

Robert C. Y. Koh, Norman H. Brooks, "Fluid Mechanics of Waste-Water Disposal in the Ocean," Annual Review of Fluid Mechanics, Vol. 7, 1975, pp. 187-211.

Jackson, George A., Robert C. Y. Koh, Norman H. Brooks, and James J. Morgan (1979), "Assessment of Alternative Strategies for Ocean Sludge Disposal into Deep Ocean Basins off Southern California," final report to the City of Los Angeles, County Sanitation Districts of Los Angeles County and County Sanitation Districts of Orange County, Environmental Quality Laboratory Report No. 14, California Institute of Technology, Pasadena, California, 121 pp., plus Appendices, September 1979.

Grace, Robert A., Marine Outfall Systems, Prentice-Hall, 1978, 600 pp.

National Oceanic and Atmospheric Administration, The Impact on Estuaries and Coastal Waters of the Ocean Disposal of Municipal Waste-Water and Its Constituents, to be published by MIT Sea Grant, 1982, (Edward Myers, Editor).